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Final Technical Report
June 1981

PRELIMINARY ENGINEERING STUDY OF LONG-LEAD TIME EQUIPMENT REQUIRED FOR LARGE LIGHTWEIGHT MIRROR MANUFACTURE

Corning Glass Works

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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PRELIMINARY ENGINEERING STUDY OF LONG-LEAD TIME EQUIPMENT REQUIRED FOR LARGE LIGHTWEIGHT MIRROR MANUFACTURE.

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10 Barry R. Stepp
Michael J. Minot

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Contractor: ~~Corning Glass Works~~
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Coremaker	Mirror Blanks	
Forming Furnace	Sealing Furnace	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This technical report develops design concepts for equipment required for the manufacture of large, lightweight mirror blanks by the fusion technique. An earlier study[1,2] identified this equipment as long lead time equipment critical to a mirror manufacturing schedule.

The equipment addressed in this report includes: 100" glassmaker furnace, core maker, annealer and fusion sealing furnace. Cost estimates to complete detailed engineering and construction of equipment are developed.

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Timing schedules for the design, construction and installation of this equipment show that the core maker is the longest delivery item, requiring 25 months to complete. No technical problems have been identified. The report recommends that detail design engineering on critical equipment and preliminary engineering on other equipment be initiated.

[1] Bliss, W.E., Cleveland, "Manufacture Study for a Four Meter Lightweight Mirror". Report RADC-TR-80-103.

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GLOSSARY

Alpha - Coef. of thermal expansion.

Boule - The disc of glass formed in the furnace.

Cell - Single section of core.

Core - Hollow section in mirror center.

Crown - Refractory cover of furnace.

Ell - Half section of a cell.

Flopping - The turning over of large plates, cores or mirrors.

Flowout - Method used to produce large diameter plates from small diameter boules.

Glass - Used in the report to mean ULE™ material.

Post - Corner section to which 2 struts are sealed to form an ell.

Spider - Spring loaded lifting device made up of many cables to lift cores.

Squash - The movement applied to heated edges in ell and core making to form a seal.

Stack - Method used to produce thick sections of glass.

Standard boule - 60" (1.52m) diameter @ 1300# (590kg).

Starter strip - Section of glass used to start core manufacture.

Strut - Flat piece of glass used to form a cell.

Takeout table - Machine used to support core and move outward as it is formed.

Wax plate - A disc of glass used for chucking mirror parts.

1.0 BACKGROUND AND OBJECTIVES

The objectives of this study, as given in the statement of work are as follows:

1.1 Definition of Design Concepts

A design concept will be developed for each of the following pieces of equipment:

1. 100" furnace
2. Coremaker
3. Annealer
4. Sealing furnace

As part of the summary report, a blueprint for each of these pieces of equipment will be provided showing the general design concept. In addition to the specific equipment required, a blueprint will be provided showing the approximate location of the 100" furnace with appropriate exhaust ducting. Also, a preliminary analysis of EPA needs will be provided.

1.2 Cost Estimates

In addition to design concepts, the preliminary engineering or scope study will provide firm estimates of costs for doing the detailed engineering required to construct the cited equipment.

1.3 Construction Costs

The summary report will also include range cost estimates for constructing the equipment necessary for the Large Lightweight Mirror Construction.

1.4 Schedule

The report will summarize timing estimates for the completion of the detailed engineering and construction of equipment. Long lead time parts will be identified.

1.5 Contractor will review and update the Large Lightweight Fabrication program presented in Report RADC-TR 80-103 including all key milestones and showing the effort interrelationships.

1.6 Contour Grinder

During the procurement of the Contour Grinder, detailed designs and specifications for the unit will be developed. Contractor will make all plant preparations for installation of the Contour Grinder and demonstrate proper operation upon completion of installation.

2.0 TECHNICAL REPORT SUMMARY

This study has been undertaken to provide data preparatory to detail design engineering on equipment for manufacture of a large lightweight mirror blank.

2.1 Assumptions

2.1.1 Assumptions of size for the mirror blank are detailed in Table 9-1. The basic design for the mirror blank is assumed to be similar to recently manufactured space telescope blanks for NASA. Assumptions of mirror blank size and weight were necessary in order to develop equipment parameters.

2.1.2 All costs are in 1980 U.S. dollars.

2.1.3 Cost estimates for detailed engineering assumes that all engineering information will be generated to CGW standards. Drawing will have non-metric dimensions.

2.1.4 No costs are included for project supervision, coordination, interim reports, or final report generation.

2.1.5 Equipment costs assume building and site preparations are complete and services available within 6 feet of machinery.

2.1.6 Schedules assume reasonable preliminary planning time is available prior to commitment to schedules.

2.1.7 Engineering cost estimates include technical support through construction and equipment start-up. Process development and documentation (SOP's) costs are not included.

2.1.8 It is assumed that existing facilities are adequate for all equipment.

2.2 Methods

The investigation was centered around improvement and design scale-up of existing equipment currently utilized for blank manufacture. The purpose was to identify potential technical problems in equipment scale-up if they exist. Manufacturing requirements and existing equipment were reviewed as a base for developing concepts for new equipment. Design concepts, costs, timing and studies necessary for reduction of concepts to practice were developed.

2.3 Results

No major technical problems were identified which would hinder or restrict a program to produce large lightweight mirrors through scale-up of existing equipment. Impact on emissions from manufacturing processes could be major. Conformance to emission control laws will require further study as defined in paragraph 3.6. Feasibility of design of equipment or operational success is not in question in these areas, but study is necessary to identify the most desirable pollution control systems.

2.4 Costs

Costs are summarized below. Details are available in paragraphs 6.1 through 6.4.

Engineering	891.1	($1000)
Consultant	687.5	
Construction	1,813.8	
TOTAL	3,392.4	

2.5 Timing

Timing for design, construction and installation ranges from sixteen to twenty-five months. The longest lead time is the core maker, requiring twenty-five months to complete.

2.6 Future Activity Recommendations

Steps to be taken subsequent to this report would include:

1. Completion of preliminary engineering on equipment not covered by this study.

2. Completion of design engineering per estimates included within this study.

3. Completion of equipment and facilites to produce the large lightweight mirror blank.

4. Completion of engineering study on coremaker burners as defined in this report.

5. Completion of engineering studies as defined in "Manufacturing Study for a Lightweight Mirror" - report RADC-TR-80-103.

6. Long lead time item procurement where impact to customer schedule is deemed significant.

3.0 PRELIMINARY ENGINEERING - LONG LEAD TIME EQUIPMENT

3.1 100" Glassmaking Furnace

Current furnace operation indicates that design of this size furnace will be successful by scale up of existing equipment.

3.1.1 Furnace (Illustration 8.1)

This furnace will be used for the manufacture of 100" (2.54m) boules for the fabrication of 160" (4m) plates free from vertical seams for Large Light Weight Mirrors (LLWM). The main function of this furnace is to laydown ULE(TM) material by flame hydrolysis of batch materials carried to the furnace burners by oxygen gas and to fuse this material into a glass boule.

The material is introduced through natural gas fired burners and deposited onto a rotating mold that is continuously lowered to maintain a constant distance from the furnace burners, located in the crown, to the top of the boule. Normal operating temperature for the furnace is 1675°C ± 25°C.

An exhaust system connected to the furnace at four points will carry off the products of combustion and the excess material to a pollution control system. This is depicted in illustration 8-6. The furnace structure will have two doors which will open to expose the entire diameter of the furance interior for unloading of boules.

The furnace controls for firing and monitoring the burners and controlling the raw material for making the boule are located in a panel adjacent to the furnace.

Successful operation of the furnace will require a development program.

3.1.2 Laydown Table and Drive System (Illustration 8.1)

The laydown table and drive system for a 100" (2.540m) forming furnace would consist of newly designed 121" (3.073m) diameter table and drive system, to support and rotate the refractory base which contains the glass as it is formed.

Table construction would be similar to Corning's existing smaller laydown tables, fabricated of steel top and bottom plates welded to a hub and wide flange beam framework. Thermal shielding to protect the drive system would be fastened to the outer edge of the table. The drive system is based on an existing propreitary Corning design which has been evaluated to determine the required modifications. These evaluations consisted of both mathematical modeling and shop trials.

The table sub-assembly would be supported by three heavy duty swivel casters mounted on equally spaced arms extending from the gear case of the drive system.

A motorized sub-assembly located beneath the caster arms would support the drive system and permit height adjustment of the laydown table while in operation.

3.1.3 Furnace Location (Illustration 8.6)

Existing storage in Furnace Room 4 will be relocated to make room for the 100" forming furnace, which will require 600 ft^2 ($56m^2$). Support and production equipment currently located in the furnace room area will stay in place.

The proposed layout for the 100" fused silica furnace shows the furnace in the northeast corner of Furnace Room 4. The burner panels will be located along the north and east walls. The furnace opens toward the center of the room to allow for ease of access.

3.2 Fusion Sealing Furnace (Illustration 8.2)

This new furnace will be used to fusion seal the component parts of a Large Lightweight Mirror. Parts placed in the furnace are heated sufficiently to allow them to flow together and then cooled rapidly to prevent sagging out of shape. The ability to rapidly heat and cool down this large furnace is critical. Existing furnaces in the Canton facility are not suitable for expansion to perform the function. The furnace will be equipped with natural gas and oxygen burners capable of providing temperatures in excess of 1700°C. The fuel mixture is introduced into the furnace through multiple burners individually controlled by flow meters housed in panels mounted adjacent to the furnace.

The cavity of the furnace is large enough to fusion seal a LLWM 160" (4m) in diameter and 30" (76m) high. The mirror blank during heating, sealing and cooling will rest on a circular table that rotates to maintain uniform temperatures throughout the parts.

The refractory surface of the table can be shaped to seal convex, concave, or plano mirror blanks or plates.

The design of this furnace is similar to existing furnaces currently in use in Corning Glass Works. No new technolgy is required for this design. Detail engineering will define such parameters as number of burners and burner layouts, thermal analysis, process gas manifold and control system.

3.3 Annealer (Illustration 8.3)

This kiln is disigned to provide a standard ULE(TM) material anneal for fusion sealed LLWM (Large Lightweight Mirrors) 160" (4m) in diameter and 30" (.76m) thick.

Crown support considerations, thermal control, and complications from consecutive expansions of existing equipment indicate that new equipment must be constructed. A new kiln will be designed conforming to current Corning Glass Works standard practice. The unit will consist of a structural steel furnace supporting insulation of refractory fiber. The mirror blank component supports will be fabricated of conventional refractory. Gas-oxygen burners will provide annealing temperatures in the range of 1050°C ± 25°C.

Specifications for alpha will dictate thermal homogeneity control. Additional study funds may be required during detail engineering, to define the degree of thermal homogeneity required.

3.4 Core Maker (Illustration 8.4)

The Core Maker will be a new, up-sized, updated machine based on Corning's existing Core Maker and operational experience utilizing the same cell fusing technology. The cost of modifications required to enlarge the current equipment dictate construction of a new machine. The new machine will be designed to build a core of 4" (101.6mm) square cells, 30 (762mm) deep, 180" (4.572m) wide when used in conjunction with a new up-sized Core Assembly Table.

The machine will consist of a welded main frame approximately 25' (7.620m) long, carriage guide and locating rails, an ell chuck and squash cylinder sub-assembly with integral burner carriage, two up-sized sealing burners, a services carriage and support frame, electrical and services controls, and portable core holding clamps (used to support the core as required during assembly), supports for unfused end struts, and dial indicators for set-up. Improvements will include auto burner ingnition and microprocessor sequencing.

3.4.1 Sealing Burner Experiments

Sealing burners are critical components of the Core, Ell, and Ring Fabrication Equipment. Burner experimentation will be required for proposed up-sizing of Corning's present burner design to 30" (762mm) in length and to determine the feasibility of fitting two such up-sized burners in a 4" (101.6mm) square cell.
The proposed burner design has a high probability of success. Although some temperature differences could be expected down the length of the burner, it is felt that proper cooling will keep thermal distortion to a minimum.

At this time, mechanical rigidity and alignment for a long burner may be a bigger potential problem than thermal distortion. It is believed that burner port location (combination of thermal distortion and mechanical alignment) must be held within 1/16" (1.588mm) to achieve an acceptable process. Consideration will be given to linking the burners at the top and/or mid-sections for greater rigidity.

The burners should fit into the 4" (101.6mm) cell without much difficulty since the basic process is similar to the present one. However, this constraint needs to be verified after the final burner design is completed.

In summary, the proposed process appears reasonable with no major foreseeable concerns.

Tasks of a Burner experimentation program would be as follows:

1. Investigation of existing burners, burner mounting and operational requirements.

2. Analyze burner distortion and establish proper cooling requirements.

3. Mechanical conceptualization and design of a prototype burner and burner mounting based on theoretical analyses and operational requirements.

4. Determine feasibility of fitting two burners opposed in a 4" (101.6mm) square cell.

5. Detailing and checking of prototype burner, and mounting drawings.

6. Procurement of two prototype burners, fixturing, and fuel control components.

7. Laboratory testing of prototype burners.

8. Production plant testing of prototype burners and verification of burner: design, mounting, operation within a 4" (101.6mm) square cell, ignition and shutdown procedures under normal and emergency conditions.

9. Revision of prototype burners, mountings and drawings based on testing.

10. Engineering documentation of production burner and mounting designs, operation and procedures for ignition and shutdown.

Costs for a burner experimentation program are included in paragraph 6.4.

3.4.2 Core Assembly Table

The Core Assembly Table will be a new, up-sized table, similar in concept, to Corning's exisiting Monolithic Conveyor Table, but specifically designed for use with a new Core Maker to assemble a mirror core.

The table would be comprised of a main frame, two wide conveyor slider beds, and a carriage weldment with a vertical graphite face 180" (4.572m) long, 28" (.711m) high, bridging both table slider beds. Two wide conveyor belts are attached to the carriage and pulled over the slider beds, carrying the assmbled core as the motorized carriage is retracted across the table. Two air brakes clamp the carriage to the main frame during cell fusion.

Provision is made to permit moving the assembly table a short distance away from the Core Maker to facilitate finished Core removal.

3.5 Contour Grinder

The new contour grinder will be manufactured by the Campbell Grinder Co. The design of the machine is basically that of a vertical boring mill with a 163" (4.14m) diameter turntable, 180" (4.57m) swing clearance and a 49" (1.24m) vertical clearance. It consists of a steel base supporting the turntable and its variable speed drive. An overhead steel bridge straddling the base and turntable will be equipped with dual variable speed grinding spindles.

Electronic numerical controls will be provided for the grinding spindles to allow maximum flexibility in generating precise surface contours. According to the manufacturers design specifications, the machine will be capable of generating surface contours to ±0.001 inches of the mathematical curve. Digital readouts will indicate position on all axes to ±0.005 inches to facilitate manual feed control and alignments, necessary for I.D. and O.D. grinding and for set-up prior to automatic contour grinding.

3.6 Pollution Control Impact (Preliminary Analysis)

Gaseous and silica particulate emissions resulting from the ULE material production have a potential pollution impact on the environment. It is CGW policy to operate in compliance. The Canton Plant is located within an area of New York State designated as an "attainment area" in compliance with National Ambient Air Quality standards, for particulate matter. Because of this status, new construction or modification of an air source designated as a major facility may be subject to Federal Prevention of Significant Deterioration (PSD) requirements. The USEPA has defined a major glass manufacturing plant for purposes of PSD applicability as a 250 ton/year threshold emitter. Therefore, if the

Canton Plant total potential to emit particulate matter emissions were to exceed the 250 tons/ year "trigger number" the following would be necessary: (1) that the Best Available Control Technology (BACT) air pollution control system be installed; (2) that pollutant increment increases which allow for industrial growth in an attainment area be assessed; and (3) that regulated pollutants be modeled and monitored, to assess the potential environmental impact.

3.6.1 Air Pollution Control Device

At present, it is uncertain to what extent the LLWM Project will increase air emissions. Emissions increase is contingent upon several variables. One critical variable is whether existing furnaces would continue producing new glass boules or whether they would be shut down if a new 100" furnace is required, thereby increasing emissions potential. Other variables include plant production increases, expansion into additional furnaces, laydown efficiences, days of production per year, etc. Depending on circumstances not yet defined, it is possible that the LLWM Project will increase actual emissions. If this is the case, the main stack air source permit from NYS DEC will have to be modified to reflect this change. Granting of the modification request is based on State environmental guidelines and <u>can be a discretionary decision on the agency's part</u>. If the particulate emissions exceed a 250 tons/year "trigger number", there would be an extensive, complicated, and lengthy review process under USEPA Prevention of Significant Deterioration Rules. These rules require an environmental assessment to determine what increases in pollutant level will be caused by the proposed project and would require that the Best Available Control Technology (BACT) air pollution control devices be installed, at significant expense, as well as requiring pollution monitoring and modeling.

Air pollution control devices will be time consuming and expensive, requiring twelve months of pilot testing plus 30 months for design and installation. Therefore, engineering and air pollution control system pilot programs should be underway in 1981.

3.6.2 Air Pollution Control System Pilot Studies

Current air pollution control technology necessitates equipment trials prior to detail engineering. In these trials, the various alternative pollution control systems would be evaluated for control efficiency as well as operating and maintenance costs. Final design for a full-scale control system would be based on these evaluations.

Past experience, gained from designing and installing air pollution control systems at other Corning Glass Works facilities, indicates that a pilot program will require from 9 to 12 months. The estimated cost for a program of this type is in the range of $150,000 to $250,000.

3.6.3 Other Pollution Control Devices

The plant currently has a NYS DEC industrial wastewater discharge permit. NYS DEC is the lead agency with which the plant must work to obtain any changes in the wastewater discharge from the existing permit.

Compliance with State and Federal regulations for solid waste disposal would be necessary for any new or additional wastes. NYS DEC is the lead agency regulating disposal of all non-hazardous wastes. The USEPA is currently the lead agency regulating disposal of all hazardous wastes as defined by the Resource Conservation and Recovery Act of 1976, Subtitle C. With regard to the LLWM Project, wastewater and solid waste discharges will most likely increase but should not pose any significant problems, although handling and disposal practices might have to be modified at a moderate cost. It should be noted that a wastewater treatment system may be necessary if an air pollution device is required, which includes some form of gas scrubbing, in addition to particulate matter removal. In this case, installation of a control device may be even more complex and costly than at first expected.

4.0 CONCLUSIONS

4.1 General

Long lead time equipment can be constructed to produce a large lightweight mirror blank utilizing mirror construction methods described in RADC-TR-80-103:

4.1.1 No technical or process problems are known which prevent mirror construction.

4.1.2 Equipment for fabrication of the blank can be designed and constructed by extension of existing technologies.

4.1.3 Deviations from information described in RADC-TR-80-103 are as identified below.

4.2 Equipment

4.2.1 100" Glassmaking Furnace

The 100" forming furnace will be new equipment of enlarged design utilizing a greater number of existing design burners.

4.2.2 Fusion Sealing Furnace

A new sealing furnace sized to the blank must be designed to provide facilities to assemble plates and fire final mirror.

4.2.3 Annealer

Engineering evaluations indicating that it is impractial to expand existing equipment. A new annealer will be constructed.

4.2.4 Coremaker

The core maker will require an expanded design and construction of new equipment.

4.2.5 Contour Grinder

The new contour grinder will provide the size capacity and the grinding precision to prepare mirror blank component parts for assembly.

4.3 Development Programs

4.3.1 A burner development program will be required for the coremaker.

4.3.2 Development programs delineated in RADC-TC-80-103 are still required as follows:

1. 2400 lb. (1089 kg) boule development.
2. Core sealing development.

4.3.3 An equipment piloting program for air pollution control devices may be required.

5.0 RECOMMENDATIONS

5.1 Support to determine other equipment necessary and complete preliminary engineering on those items.

5.2 Support of detail engineering and procurement of long lead time equipment.

5.3 Combine program phases of preliminary engineering, detail engineering and procurement of equipment to a single contract to minimize time delay to construct blanks.

5.4 Define blank procurement program sufficiently to allow determination of detailed equipment necessary for pollution control.

5.5 Initiate development programs as delineated in this report and RADC-TR-80-103.

5.6 Initiate a piloting program to define pollution control equipment if required.

6.0 COST ESTIMATES

All cost estimates in 1980 current dollars. Costs do not include contract or program administration.

		Engineering ($1000)	Consultant ($1000)	Construction ($1000)	Total ($1000)
6.1	100" Glass Making Furnaces			$ 451.8	$ 451.8
	Engineering	$ 134.7			134.7
	Consultant		$ 158.4		158.4
	Travel	23.8			23.8
	ST Cost - 100" Furnace	$ 158.5	$ 158.4	$ 451.8	$ 768.7
6.2	Sealing Furnace			$ 302.9	$ 302.9
	Engineering	$ 78.5			78.5
	Consultant		14.4		14.4
	Travel	6.0			6.0
	ST Cost - Sealing Furnace	$ 84.5	$ 14.4	$ 302.9	$ 401.8
6.3	Annealer			$ 186.0	$ 186.0
	Engineering	$ 41.5			41.5
	Consultant		$ 9.0		9.0
	Travel	1.0			1.0
	ST Cost - Annealer	$ 42.5	$ 9.0	$ 186.0	$ 237.5
6.4	Core Maker			$ 648.1	$ 648.1
	Engineering	$ 218.7			218.7
	Consultant		$ 283.8		283.8
	Travel	56.3			56.3
	ST Cost - Core Maker	$ 275.0	$ 283.8	$ 648.1	$1,206.9
6.5	Sealing Burner Experiments			$ 60.0	$ 60.0
	Engineering	$ 52.9			52.9
	Consultant		$ 15.0		15.0
	Project Expense	9.5			$ 9.5
	ST Cost - Sealing Burner Experiments	$ 62.4	$ 15.0	$ 60.0	$ 137.4

	Engineering ($1000)	Consultant ($1000)	Construction ($1000)	Total ($1000)
Sub-Total Cost	$ 622.9	$ 480.6	$1,648.8	$2,752.3
G&A 18.015	112.2	86.6		198.8
10% Handling			165.0	165.0
Target Cost	$ 735.1	$ 567.2	$1,813.8	$3,116.1
Profit - 15%	110.3	85.1	--	195.4
Selling Price	$ 845.4	$ 652.3	$1,813.8	$3,311.5

7.0 TIMING ESTIMATES and LONG LEAD TIME PARTS LIST

All estimates given in months from mutually agreeable start date. Long lead time parts are those with greater than six months procurement. Schedule charts are included in Sections 10.1 to 10.6.

7.1 100" Glassmaking Laydown Furnace (Chart 10.2)

		Elapsed Time To Completion
7.1.1	Complete Detail Design Engineering	6 mo.
7.1.2	Complete Procurement & Fabrication	19 mo.
7.1.3	Complete Installation	21 mo.
7.1.4	Begin Development	21 mo.
7.1.5	Begin Production	26 mo.
7.1.6	Long Lead Time Parts List:	
	Table Drive	19 mo.
	Exhaust Fans	6 mo.

7.2 Fusion Sealing Furnace (Chart 10.3)

7.2.1	Complete Detail Design Engineering	5 mo.
7.2.2	Complete Procurement & Fabrication	13 mo.
7.2.3	Complete Installation	17 mo.
7.2.4	Available for Sealing	17 mo.
7.2.5	Long Lead Time Parts List:	
	Table Drive	6 mo.
	Exhaust Fans	6 mo.

7.3 Annealer (Chart 10.4)

7.3.1	Complete Detail Design Engineering	4 mo.
7.3.2	Complete Procurement & Fabrication	14 mo.
7.3.3	Complete Installation	15 mo.
7.3.4	Available for Operation	16 mo.
7.3.5	Long Lead Time Parts:	
	-None greater than six months	

7.4 Core Maker (Chart 10.5)

7.4.1	Complete Detail Engineering	10 mo.
7.4.2	Complete Procurement & Fabrication	22 mo.
7.4.3	Complete Installation	25 mo.
7.4.4	Available for Operation	25 mo.
7.4.5	Long Lead Time Parts List:	
	-None greater than six months	

7.5 Contour Grinder (Chart 10.6)

7.6.1	Complete Design Engineering	7/1/81
7.6.2	Complete Procurement	5/1/82
7.6.3	Complete Installation	7/1/82
7.6.4	Available for Operation	7/1/82

8.0 ILLUSTRATIONS

Key to Illustrations

Illustration 8.1 100" Forming Furnace

The furnace, laydown table, drive system, and fume ducting are shown in isometric view.

Illustration 8.2 Sealing Furnace

The proposed sealing furnace design is shown in plan and elevation. Letters refer to items listed below:

A	-	Panel Board
B	-	Flow Meters & Valves
C	-	Hoses to Burners - 5/Burner
D	-	Crown Supports
E	-	Catwalk
F	-	Burner Hose Rack
G	-	Burner Rack and Crown Supports
H	-	Burners
J	-	Crown - (H_2O Cooled)
K	-	Walls - 1FB3000
L	-	Table Insulation Graded IFB - K3000-D2600-D2000
M	-	Casters
N	-	160" Plate
P	-	Drive Unit
R	-	Motor
S	-	Duff-Norton Jacks
T	-	Jack Posts - (3)
V	-	Rotating Table

Illustration 8.3 Annealer

The proposed annealer design is shown in plan and elevation. Letters refer to items listed below:

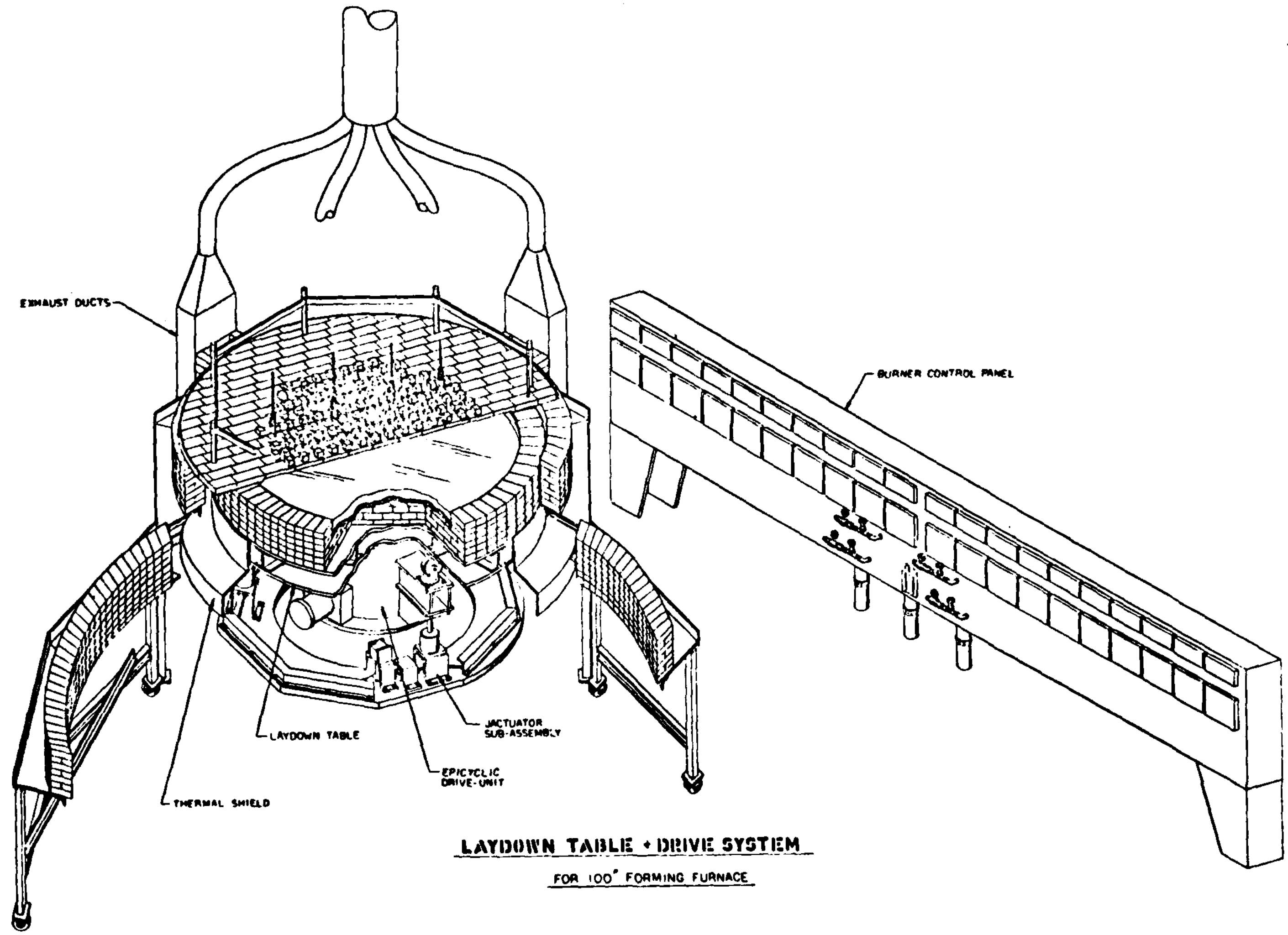
A	-	Fiber Blanket in Doors
B	-	Hearth Tile
C	-	IFB Insulating Fire Brick
D	-	Upper Wall Burners
E	-	Burners - (Near Side)
F	-	Burners - (Far Side)
G	-	Counterweight
H	-	Fiber Blanket - Suspended Crown Construction
I	-	Access Door at Each End
J	-	Hearth Tile

Illustration 8.4   Core Maker

The coremaker and assembly table are shown in isometric view.

Illustration 8.5   100" Glassmaking Furnace Location

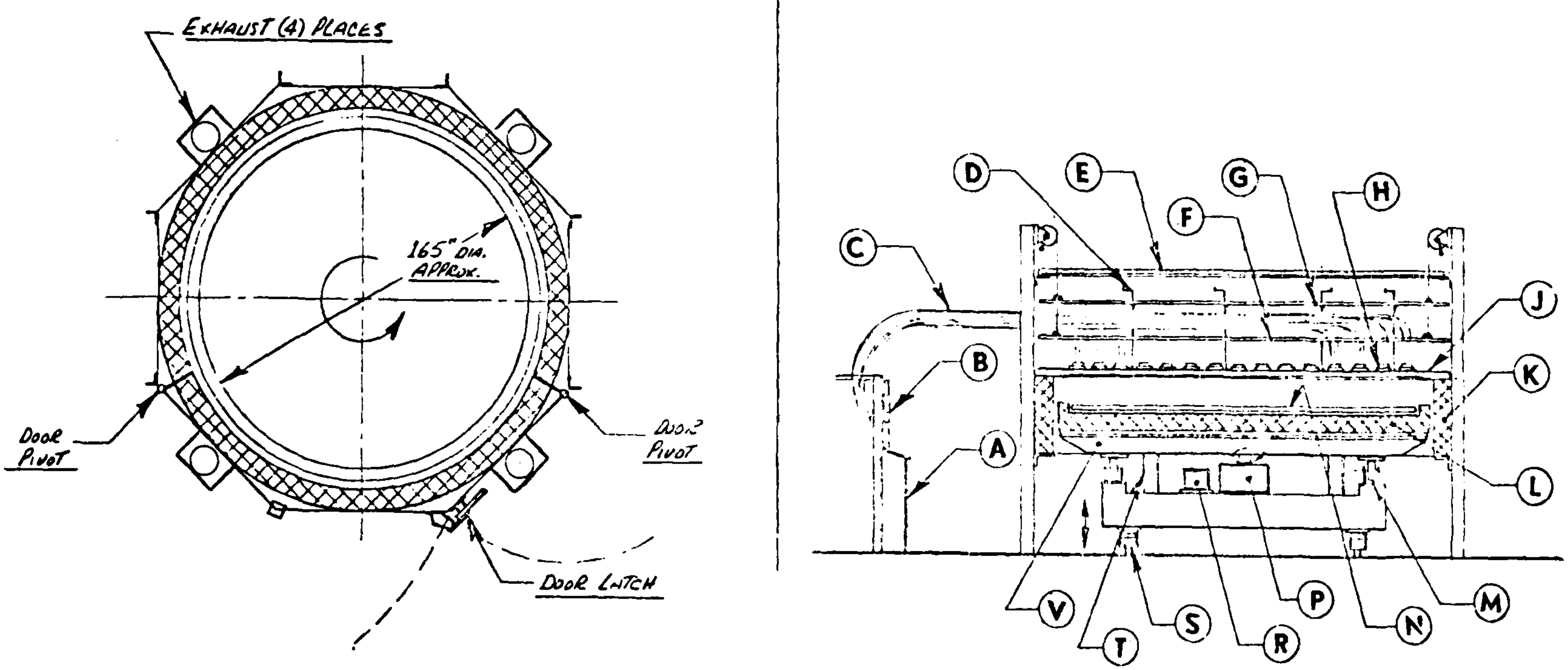
Furnace room four at the Canton Plant is shown in plan with the 100" glassmaking furnace and associated ducting location in the northeast corner.



LAYDOWN TABLE + DRIVE SYSTEM

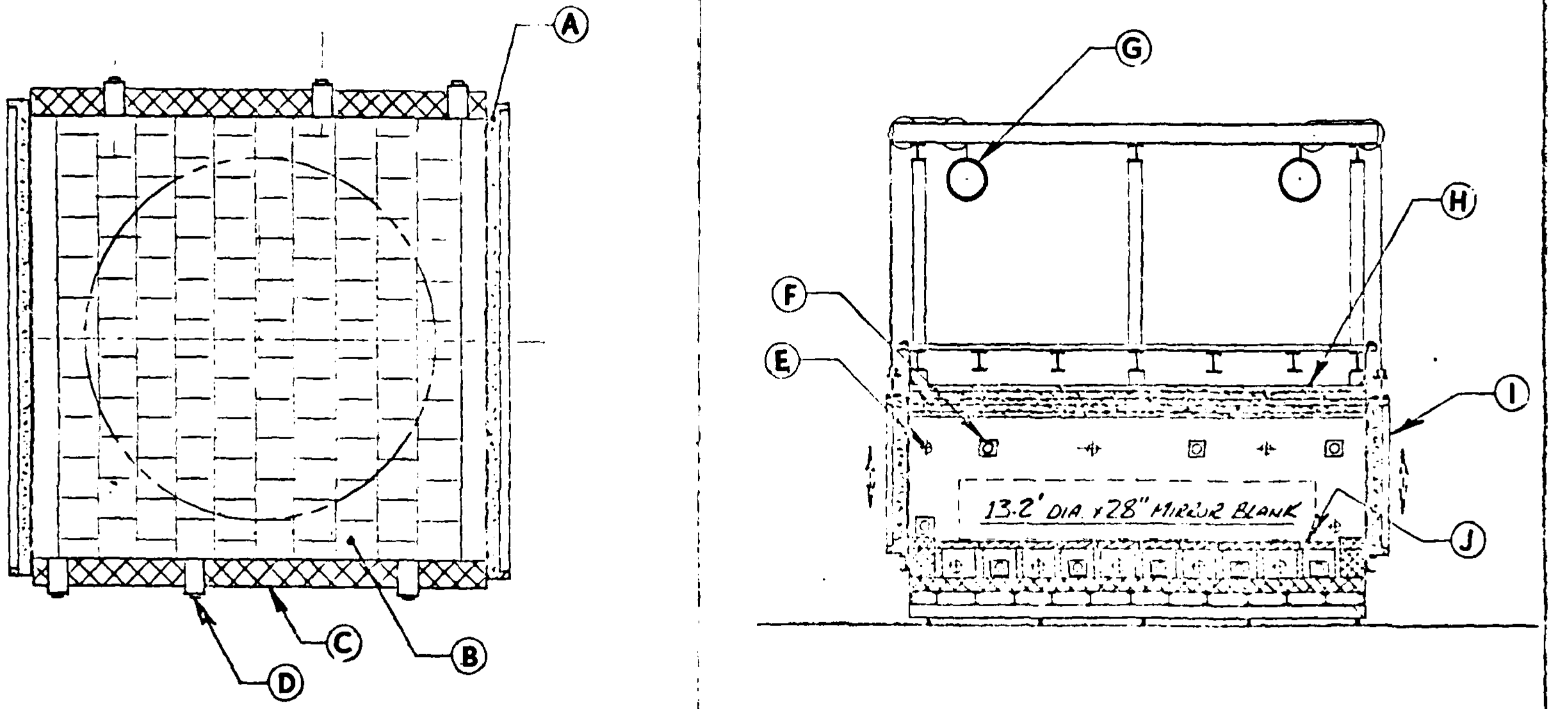
FOR 100" FORMING FURNACE

ILLUSTRATION 8.1



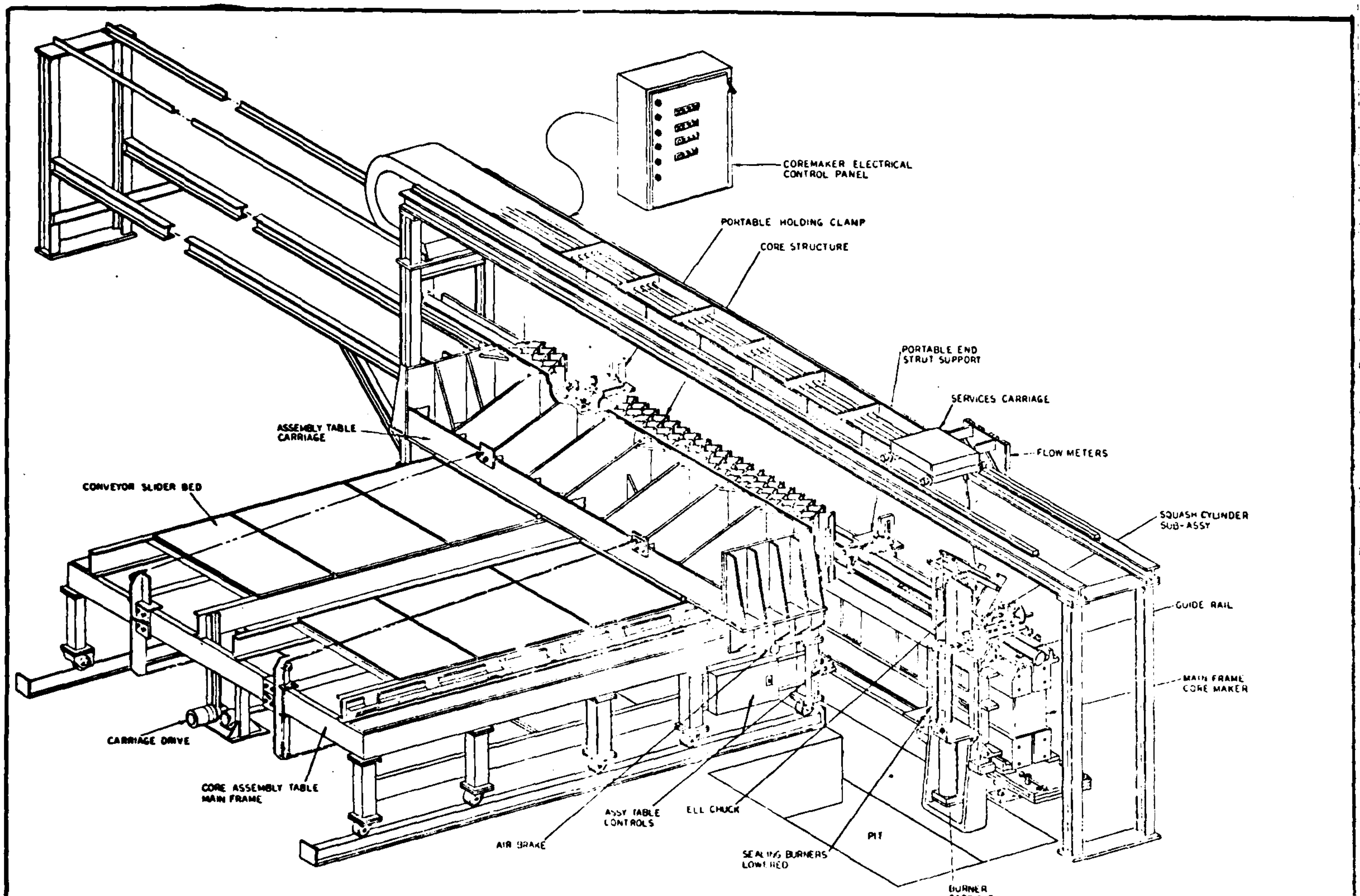
SEALING FURNACE

ILLUSTRATION 8.2



ANNEALER

ILLUSTRATION 8.3



CORE MAKER - ASSEMBLY TABLE

ILLUSTRATION 8.4

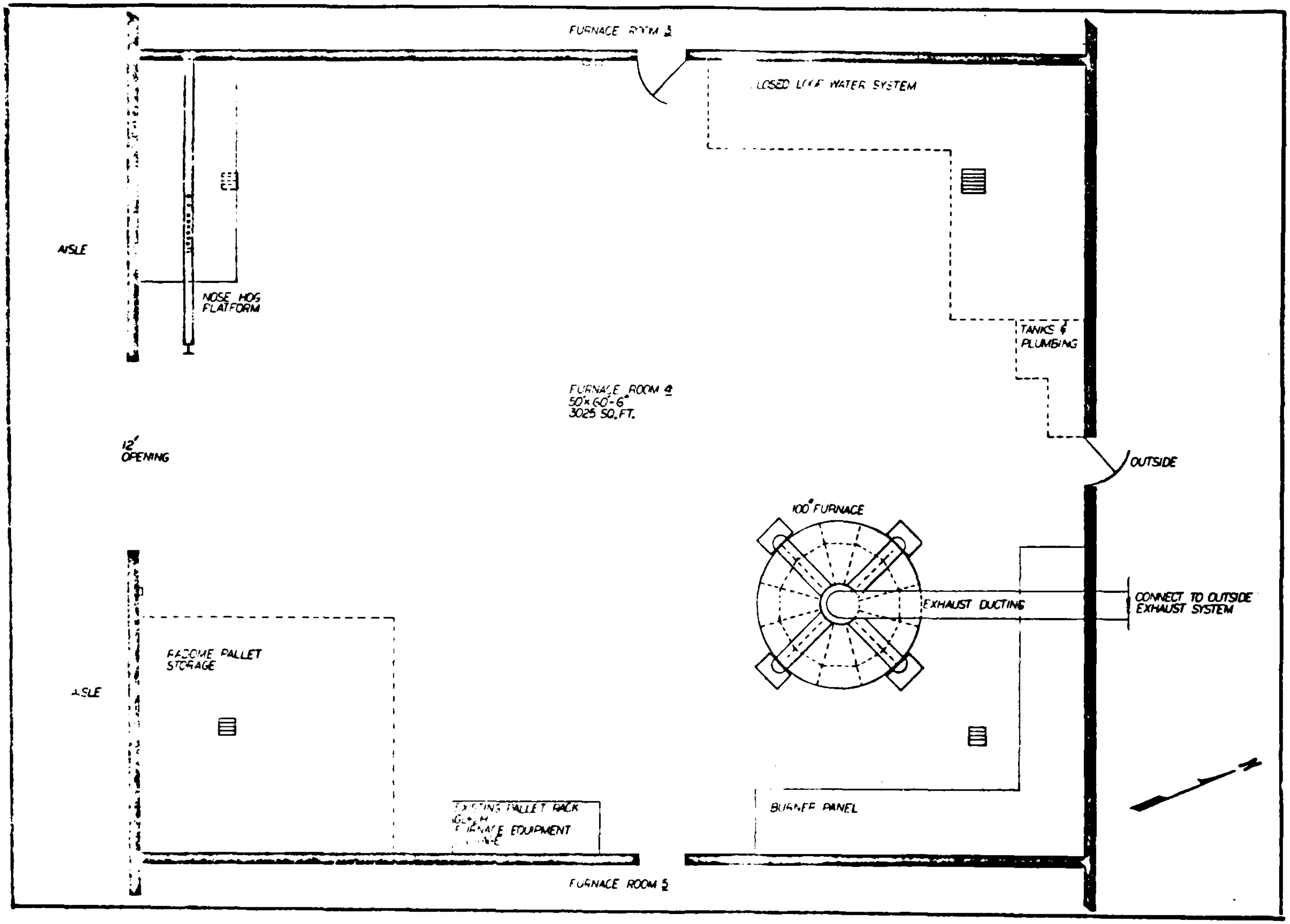
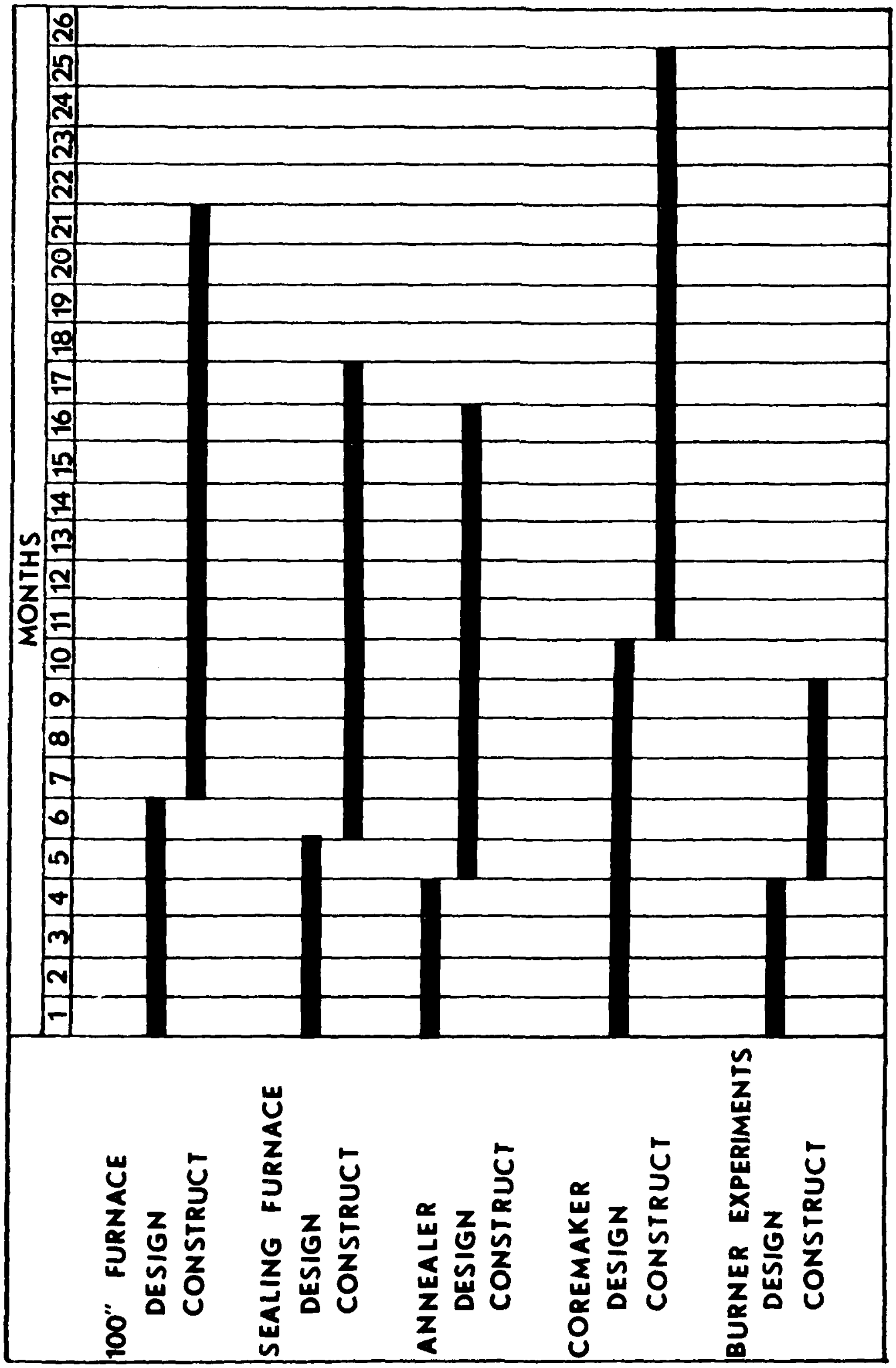


ILLUSTRATION 8.5

TABLE 9-1

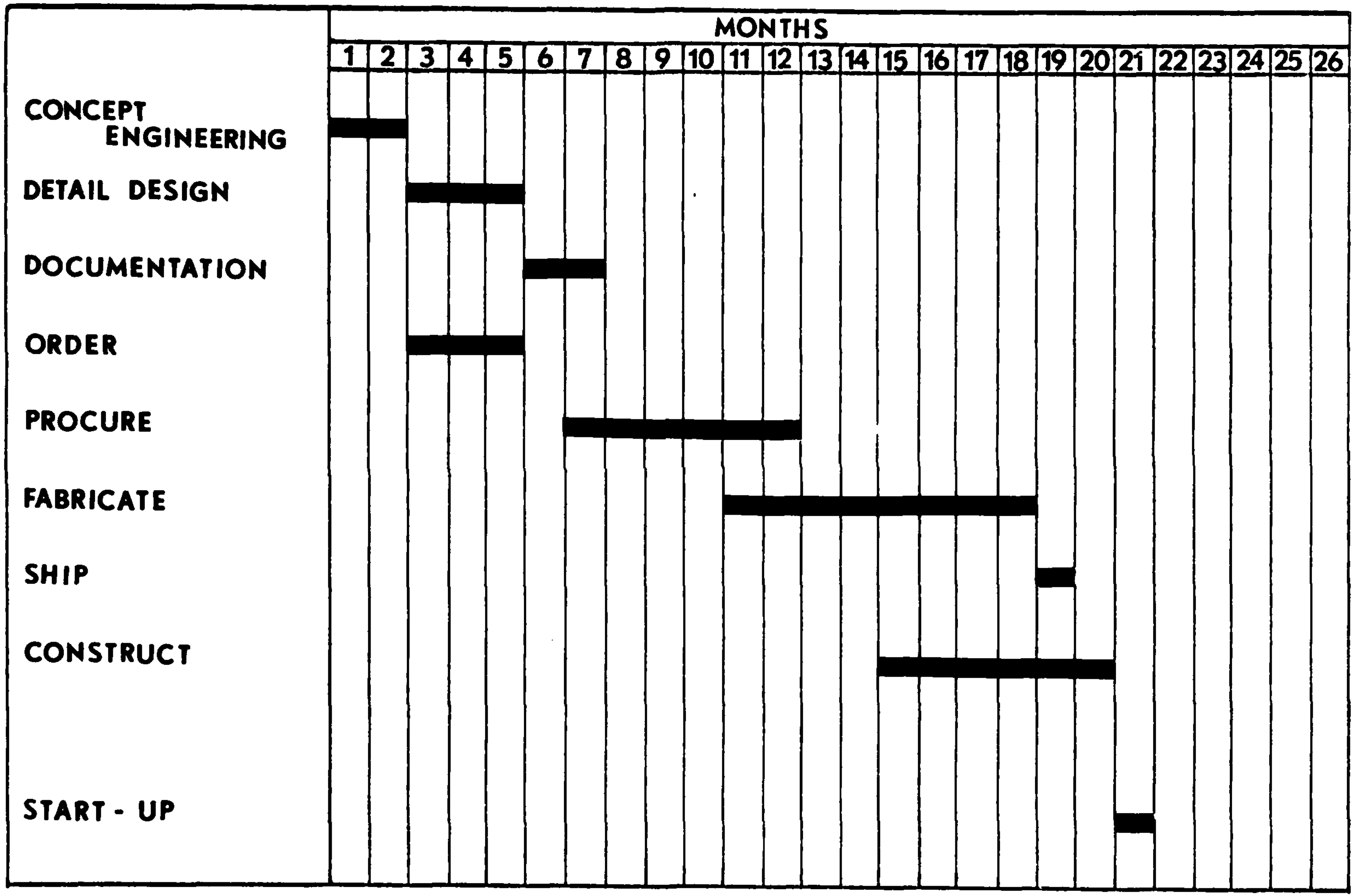
MIRROR BLANK SPECIFICATIONS

Diameter (157.48")	4.00 meters
Aspect Ratio	7-1
Thickness (22.50")	0.57 meters
Radius of Curvature (480.00")	12.19 meters
Center Hole (24") to	0.61 meters
(36")	0.91 meters
Strut Thickness	5.08 mm (.200")
Strut Size	10.16 cm (4.00")
Blank Back & Front Plate Thickness	3.81 cm (1.50")
Mirror Blank Weight (approximately)	9000 lbs.



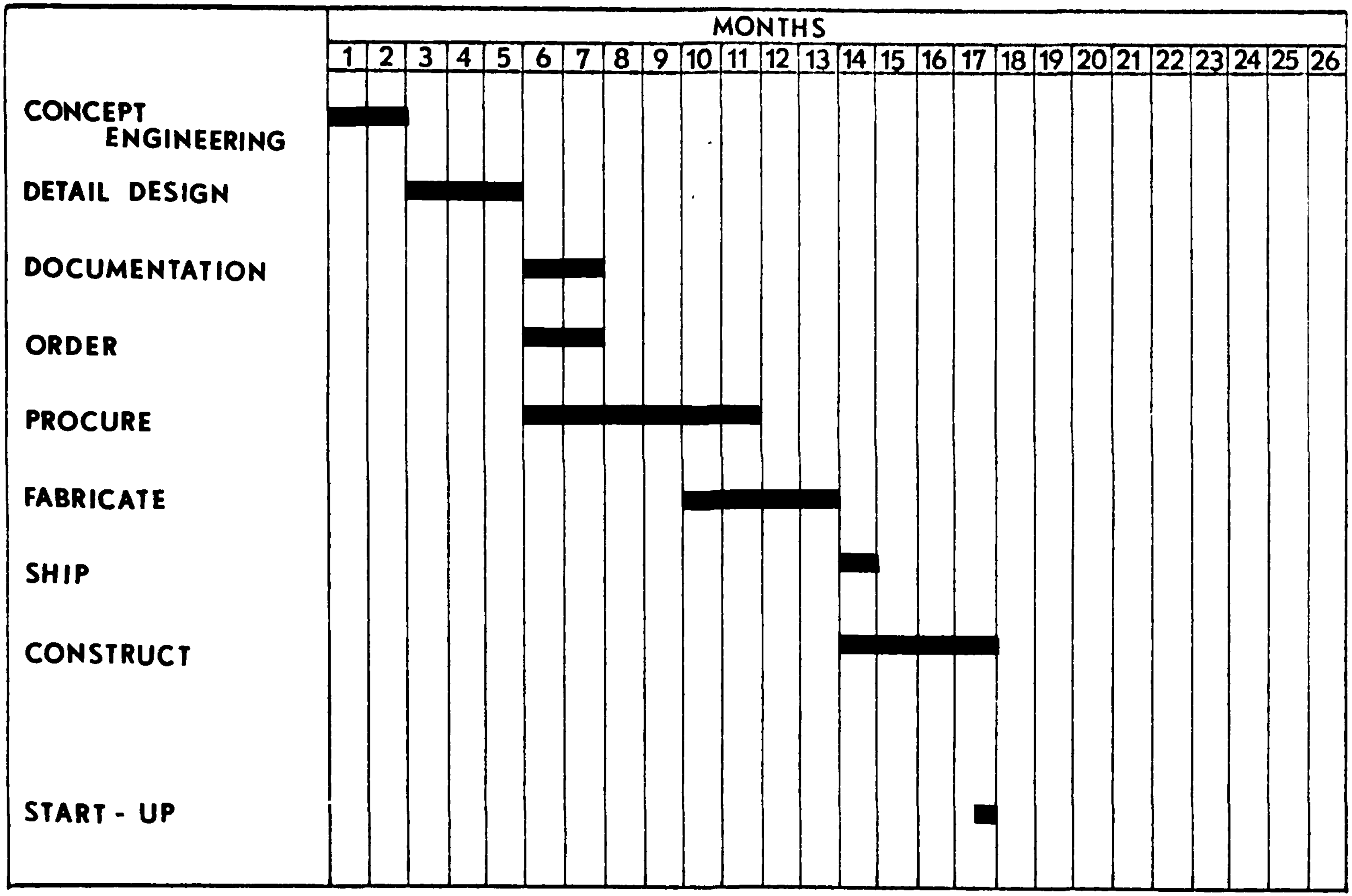
SCHEDULE SUMMARY

CHART 10.1



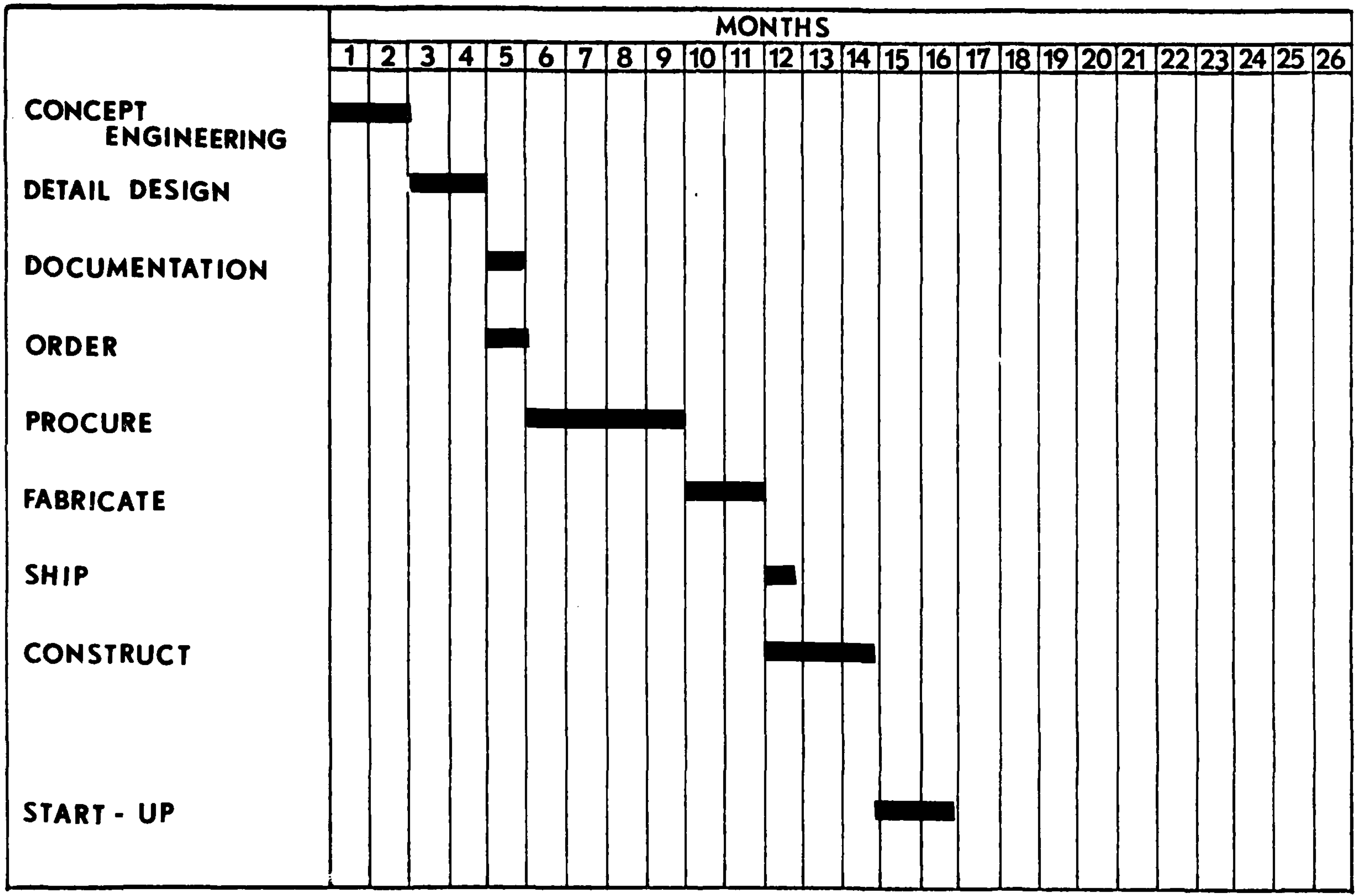
100" GLASSMAKING FURNACE

CHART 10.2



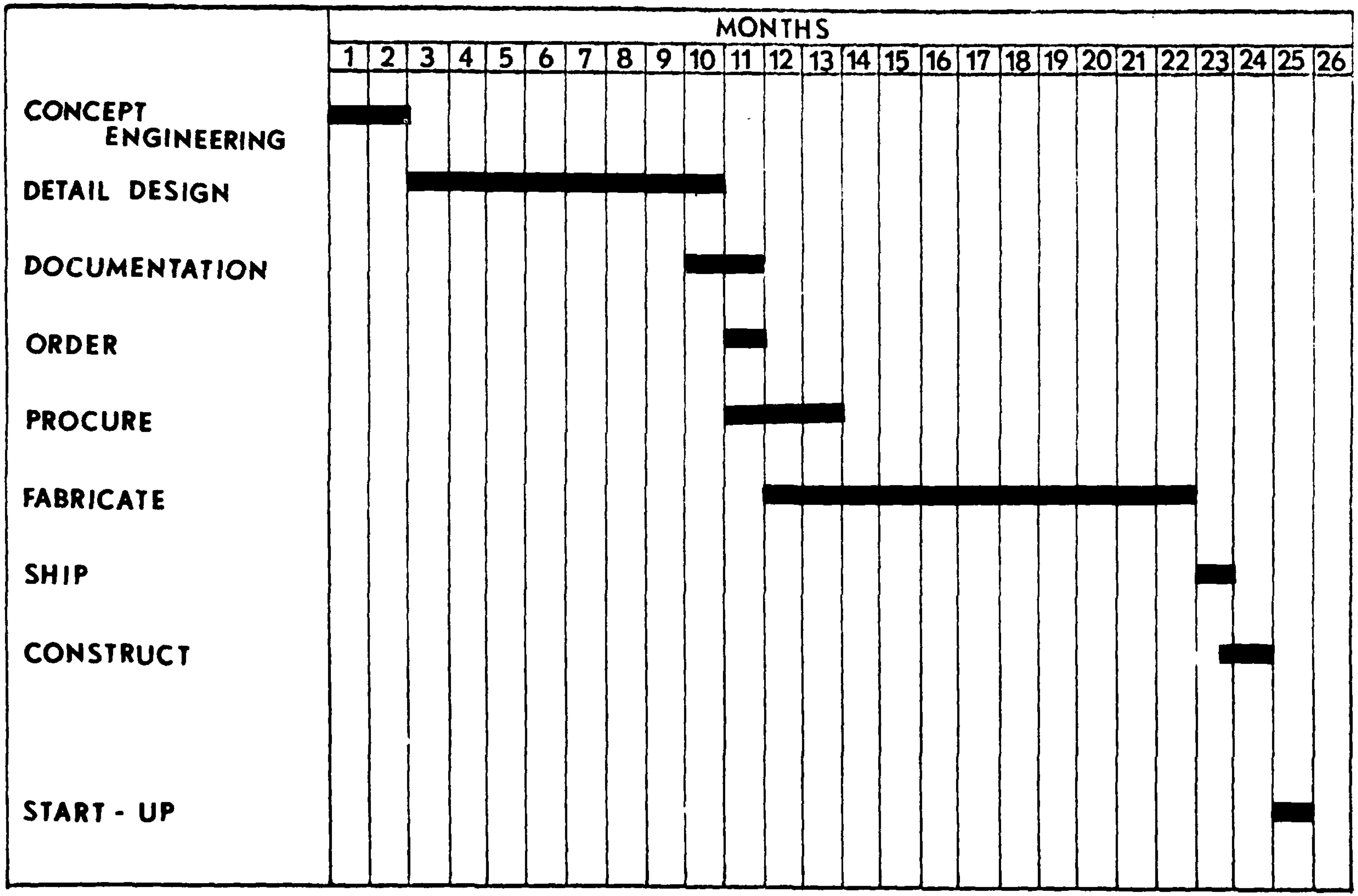
SEALING FURNACE

CHART 10.3



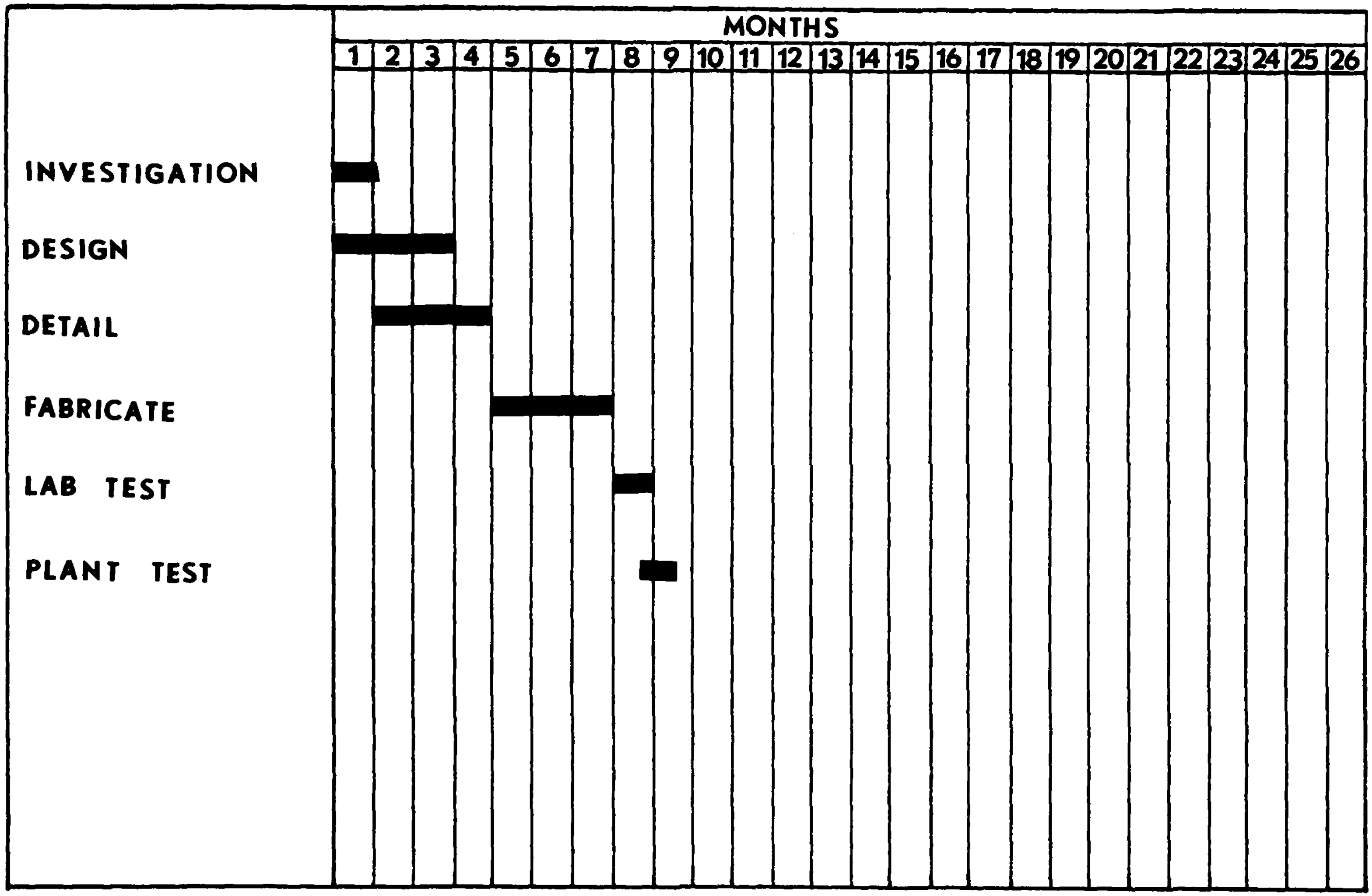
ANNEALER

CHART 10.4



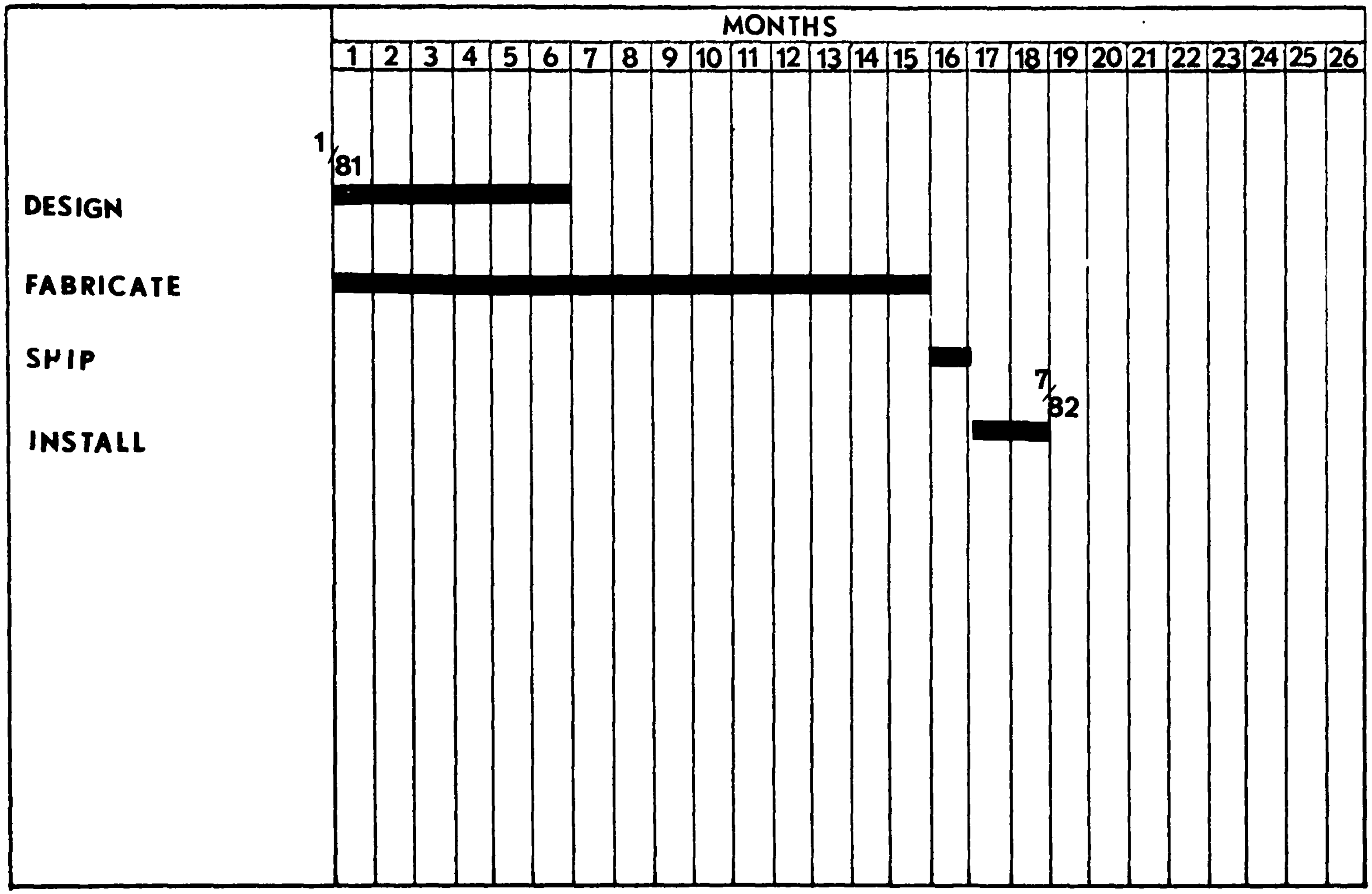
COREMAKER

CHART 10.5



BURNER EXPERIMENTS

CHART 10.5.1



GRINDER

CHART 10.6

ACKNOWLEDGEMENTS

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